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Morphology of female genitalia of tabanids in Hokkaido, Japan (Diptera: Tabanidae)

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Abstract: 【Aim】 This study aims to estimate and verify the roles of genitalia of tabanids in taxonomy with species from Hokkaido, Japan. 【Methods】 Samples of tabanid adults from Hokkaido soaked in physiological saline were dissected in petri dish by needle and tweezers under a binocular microscope and drawn. The morphological characteristics of the tergites 9 and 10, the cercus, sternite 8, the spermathecae, the spermathecal duct and the genital fork were observed and presented. 【Results】 In total 38 species of 3 subfamilies and 7 genera of tabanids have been recorded from Hokkaido. The main features of the female genitalia of 24 species of 3 subfamilies and 6 genera of tabanids in Hokkaido were observed and described here. There are the differences at the subfamily level. However, among genera, it is difficult to establish a way to determine the common points. Among species, similarities are seen only within the genus *Chrysops*. In other genera, the species are diversified. Consequently, for subfamily-level classification, the characteristics of tergite 9, sternite 8 and the spermathecae are enough for separation; while for genus- and species-level classification, the combined characteristics of tergite 9, tergite 10, the cercus, sternite 8, the spermathecae, the spermathecal duct and the genital fork must be compared. Keys to female genitalia of tabanids are provided. 【Conclusion】 Genitalia is a critical characteristic to classification in Tabanidae as in many other insects, which is significant to facilitate the development of taxonomy and phylogenesis. This is the first systematic study on the female genitalia of the tabanids in Hokkaido.

Key words: Diptera; Tabanidae; taxonomy; female genitalia; morphology; Hokkaido; Japan

1 INTRODUCTION

Tabanids are hematophagous flies of the family Tabanidae, belonging to the order Diptera. Based on the shapes of antennae in Diptera, tabanids have been assigned to Brachycera (Oldroyd, 1952; Murdoch and Takahasi, 1969; Thompson and Pape, 2010; Abu El-Hassan *et al.*, 2013). This is the most primary and important aspect of tabanid classification to separate from Culicidae and Muscidae (Oldroyd, 1952; Murdoch and Takahasi, 1969). Tabanids include three subfamilies, nine tribes, 137 genera, and approximately 4 500 species known in the world (Xu and Sun, 2013) and 38 species of 7 genera are recorded from Hokkaido (Sasaki and Watanabe, 2016). Among people with livestock animals or those who engage in outdoor activities, tabanids are commonly known as horseflies, deerflies, or clegs (Strother, 1999; Thompson and Pape, 2010; Abu El-Hassan *et al.*, 2013). To obtain nutrition for the growth of ovaries, the female of many species is one of the most important blood-sucking pests in the world (Wang, 1983; Hunter and Ossowski, 1999; Altunsoy and Kiliç, 2012; Muller *et al.*, 2012; Abu El-Hassan *et al.*, 2013). They act as both biological and mechanical vectors of human and livestock diseases caused by numerous viral, bacterial, protozoan, and filarial nematodes (Krinsky, 1976; Foil, 1989; Banerjee *et al.*, 2015). For example, trypanosomiasis, or "Surra disease" is caused by *Trypanosoma evansi* (Steel) and transmitted by tabanids (Wang, 1983; Foil, 1989; Diall *et al.*, 1993; Omer *et al.*, 1998; Delafosse and Doutoum, 2004; Hasan *et al.*, 2006; Muller *et al.*, 2012); and loiasis caused by *loa-loa* is also transmitted by tabanids (Kettle, 1984; Padgett and Jacobsen, 2008; Muller *et al.*, 2012). Therefore, tabanids have been regarded as important insects in human society for both medical and veterinary points of view

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(Murdoch and Takahasi 1969; Xu and Sun, 2013; Sasaki and Watanabe, 2016).

In spite of their high importance as pests and disease vectors, taxonomic studies are not sufficiently advanced (Mackerras *et al*., 2008; Banerjee *et al*., 2015). Species identification of tabanids is difficult in the absence of a trained taxonomist (Lessard and Yeates, 2011, 2012). The reasons for this include the lack of stable external taxonomic characteristics of some specimens, and morphologically closely related species of some of the same genera (Ovazza and Taufflieb, 1954; Murdoch and Takahasi, 1959; Lessard and Yeates, 2011, 2012).

In many species, the genitalia are critical as characteristics for classification (Tanaka *et al*., 1979; Maekawa *et al*., 2016; Miyagi *et al*., 2017). To date, a few studies on the female genitalia of Japanese Tabanidae have been conducted (Iwata and Nagotomi, 1976; Nagatomi and Iwata, 1976, 1978), but much remains to be done. Brygoo (1950) thought that the topic was unworthy of further research after he had dissected several species. After his study on three species of female *Therioplectes*, Collin (1940) suggested that the cercus and the sternite may be useful for classification. Oldroyd (1952) noted that certain features could be used in some species for classification (Ovazza and Taufflieb, 1954). Mackerras (1956) stated that " Genitalia do not usually help in discriminating between genera or species. There are a few exceptions however, and these are occasionally so useful that dissection, at least of Pangoniinae, would always seem to be justified. " The same also said by Lessard and Yeates (2011, 2012), who nevertheless pointed out that the limitations of genital morphology for identifications below tribal level make species classification difficult (Lessard and Yeates, 2011, 2012). Murdoch and Takahasi (1959) stated that the primary characteristics showing the greatest variability are the shape of sternite 10, the cerci, and the shape of the genital fork. When they dissected and compared the *Tabanus amaenus* Group, characteristics showing less variation but still having taxonomic value were observed in tergite 8, tergite 9, the spermathecae and the mushroom-shaped ends of the spermathecal ducts (Murdoch and Takahasi, 1959). These results are well known thanks to the discussion provided by Stuckenberg (1973).

We attempted to find a way to make identification easy. In this article, we describe and illustrate the female genitalia of 24 species belonging to 6 genera of Tabanidae, and make a key to species and genera in order to evaluate and confirm the role of female genitalia as characteristics for identification among the various subfamilies, genera and species.

2 MATERIAS AND METHODS

We examined tabanids belonging to 3 subfamilies, 6 genera and 24 species: *Tabanus trigonus* Coquillett, 1898; *T. nipponicus* Murdoch *et* Takahasi, 1969; *T. rufidens* (Bigot, 1887); *T. sapporoensis* Shiraki, 1919; *T. iyoensis* Shiraki, 1919; *T. kinoshitai* Kono *et* Takahasi, 1939; *T. mandarinus* Coquillett, 1898; *T. katoi* Kono *et* Takahasi, 1940; *T. chrysurus* Loew, 1858; *T. fulvimedioides* Shiraki, 1919; *T. pallidiventris* Olsoufiev, 1937; *Hybomitra distinguenda* (Verrall, 1909); *H. hirticeps* (Loew, 1858); *H. tarandina* (Linnaeus, 1758); *H. olsoi* Takahasi, 1962; *H. montana* (Meigen, 1820); *Haematopota tristis* Bigot, 1891; *Hae. tamerlani* Szilady, 1923; *Atylotus horvathi* (Szilady, 1926); *Chrysops suavis* Loew, 1858; *C. japonicus* Wiedemann, 1828; *C. nigripes* Zetterstedt, 1840; *C. vonderwulpi* Krober, 1929 and *Stonemyia yezoensis* (Shiraki, 1919). We collected all specimens in Hokkaido, Japan by NZI trapping and hand netting. The captured flies were preserved with 70% ethyl alcohol in micro-vials until the dissection. Some examined specimens were pinned and dried, and were macerated with physiological saline just before dissection.

Specimens with physiological saline, deposited at the Laboratory of Entomology, Rakuno Gakuen University, were dissected in the petri dish with the aid of needle and tweezers under a binocular microscope. Sternite 8, tergite 9, tergite 10, the cercus, the genital fork, the spermathecae and the spermathecal duct were removed from the body and separated, and their shapes were drawn. Terminology is shown on Fig. 1.

3 RESULTS

3.1 Subfamily Pangoniinae

Genus *Stonemiya* Brennen, 1935

***Stonemyia yezoensis* (Shiraki, 1919)** (Figs. 2 – 3)

Tergite 9 not divided into a pair but connected together at middle, and right angled triangle shape, all darkened; tergite 10 trapezoid and with inner margin shorter than outer margin, all darkened; cercus scale-like, posterior margin pointed bluntly in some extent, all darkened; stergite 8 wider than long clearly, widest at middle, hexagon-like, with anterior margin nearly straight, and posterior margin

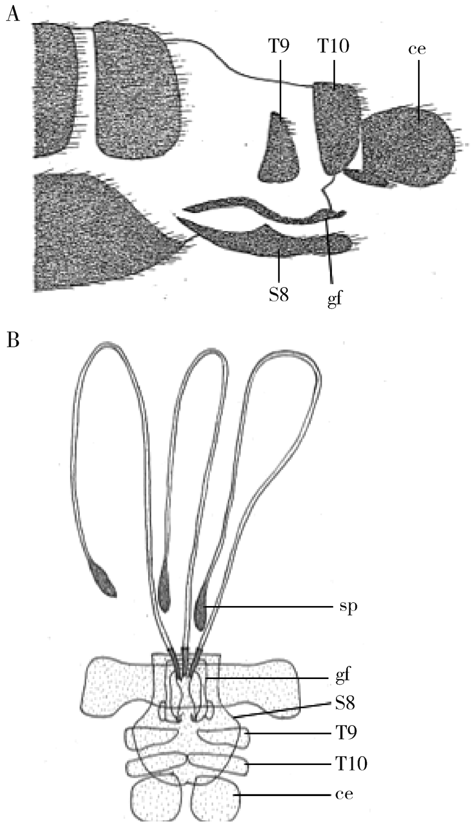

Fig. 1 Terminology of the female genitalia of tabanids
A: Lateral view of female abdominal apex; B: Female genitalia. ce: Cercus; gf: Genital fork; S8: Sternite 8; sp: Spermathecae; T9: Tergite 9; T10: Tergite 10.

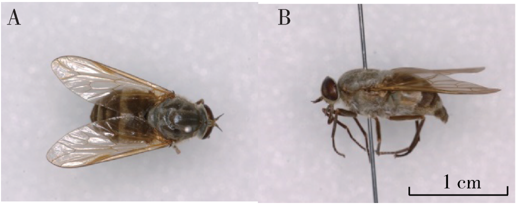

Fig. 2 Dorsal view (A) and lateral view (B) of *Stonemyia yezoensis*

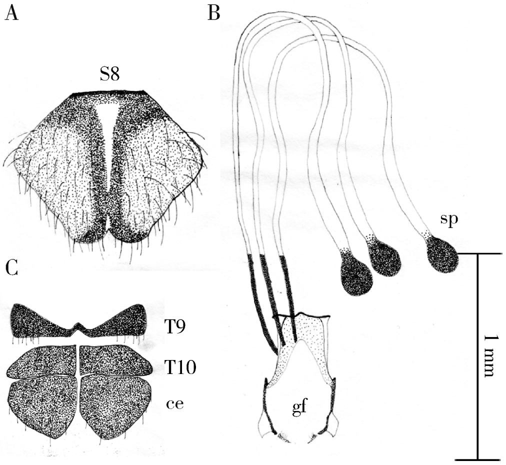

Fig. 3 Female genitalia of *Stonemyia yezoensis*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

concave distinctly, darkened at some areas; spermathcae expanding into circular, darkened; spermathecal duct a little stout at apex, and turning slender towards base, no expansion at end, transparent; genital fork tong-like, with small peltate-like membranes at both sides.

Specimen examined: 1♀, stored in 70% ethyl alcohol, Ebetsu, Hokkaido, Aug. 11, 2016, C. Yang.

3.2 Subfamily Chrysopsinae

Genus *Chrysops* Meigen, 1803

The common features in the 4 species of this genus: *Chrysops suavis*, *C. japonicus*, *C. nigripes* and *C. vonderwulpi*, are as follows: tergite 9 is quite separated from each other, tapering inward and the anterior margin appears to be concaved, excluding *C. vonderwulpi*; tergite 10 is roughly triangular but not so sharply pointed at the apex, this is the significant difference from other two subfamilies; the posterior margin of the cercus is rounded; sternite 8 is like water vat, widest near the base; the apex of the spermathecal duct is as fat as the spermathecae, and turns slender towards the base, no expansion at the basal end; the genital fork is tong-like, with two big peltate-like membranes.

Chrysops suavis Leow, 1858 (Figs. 4–5)

Tergite 9 separated and concaved distinctly at its anterior margin, crescent shape, all black; tergite 10 triangle with a dull apex tapering outward, all dark brown; cercus scale-like, rounded at

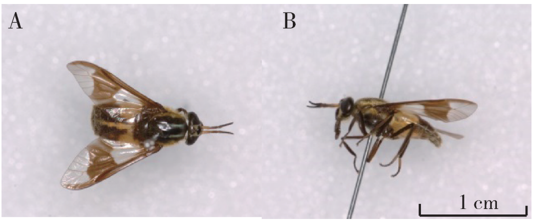

Fig. 4 Dorsal view (A) and lateral view (B) of *Chrysops suavis*

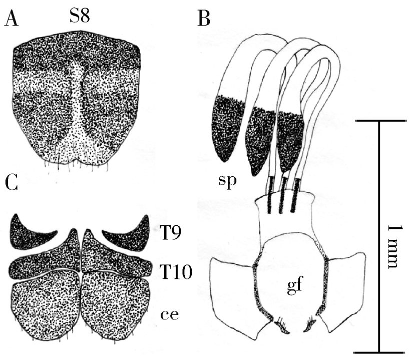

Fig. 5 Female genitalia of *Chrysops suavis*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

posterior margin, all darkened; sternite 8 vat-like, gently convex at anterior margin and lightly concaved at posterior margin, widest at base, darkened in some extent, having individual difference observable; spermathecae big compared with the whole size of spermathecal duct, and turning slender towards base, no expansion at basal end; genital fork tong-like, with small angle at each ante-lateral part and two big peltate-like membranes at basal part.

Specimens examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Jul. 17, 2015; 1♀, Jul. 15, 2016; 1♀, Aug. 11, 2016, C. Yang.

Chrysops japonicus **Wiedemann, 1833** (Figs. 6–7):

Tergite 9 similar to that of *C. suavis*, all darkened; tergite 10 sharped at inner margin; cercus comparatively short, rounded and darkened; sternite 8 also vat-like, but anterior part wider than posterior part, rounded smoothly at anterior margin, not concaved at posterior margin, but distinctly concaved at middle of outer margin; spermathecae sharp at apex, big size and longer than the other three species; spermathecal duct slender from apex to base, no expansion at end; genital fork the same with *C. suavis*, no angle.

Specimen examined: 1♀, stored in 70% ethyl alcohol, Tohbetsu, Hokkaido Jun. 18, 2015, H. Sasaki; 1♀, dried, Tohbetsu, Hokkaido, Jun. 6, 1985, H. Sasaki.

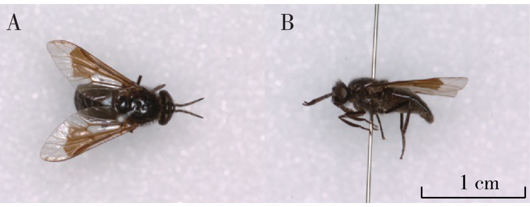

Fig. 6 Dorsal view (A) and lateral view (B) of *Chrysops japonicus*

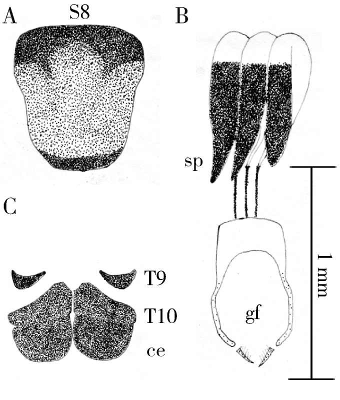

Fig. 7 Female genitalia of *Chrysops japonicus*

A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Chrysops nigripes **Zetterstedt, 1840** (Figs. 8–9):

Tergite 9 comparatively small in shape, all darkened slightly; tergite 10 sharper at outer margin, lightly darkened; cercus comparatively long, lightly darkened; sternite 8 vat-like, anterior margin little pointed, posterior margin concaved gently, base of outer margin straight, mid-distal part slightly concaved, darkened in some extent; spermathecae and spermathecal duct similar with *C. suavis*; genital fork also same with *C. suavis*, but no angle at ante-lateral part.

Specimen examined: 1♀, dried, Tsurui, Hokkaido, Jul. 30, 1975, H. Sasaki.

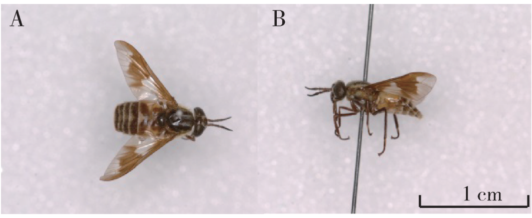

Fig. 8 Dorsal view (A) and lateral view (B) of *Chrysops nigripes*

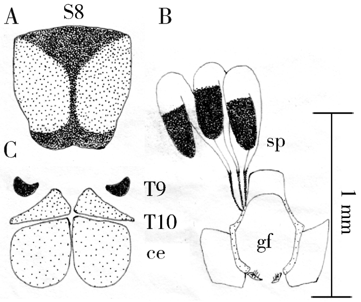

Fig. 9 Female genitalia of *Chrysops nigripes*

A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Chrysops vonderwulpi **Krober, 1885** (Figs. 10–11):

Tergite 9 small triangular, quite separated from each other, all yellowish; tergite 10 triangular, outer angle dull, inner part sharped, all yellowish; cercus comparatively long and rounded at posterior margin, all yellowish; sternite 8 close to square at front-mid part, absolutely concaved at basal lateral margin and posterior margin; spermathecae big and long, all black; spermathecal duct turning slender towards

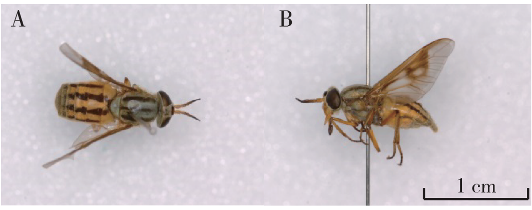

Fig. 10 Dorsal view (A) and lateral view (B) of *Chrysops vonderwulpi*

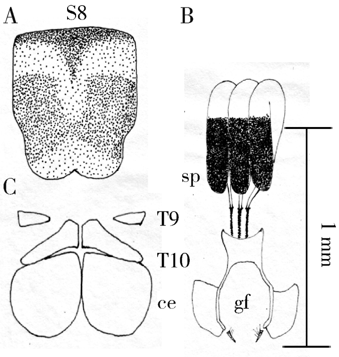

Fig. 11 Female genitalia of *Chrysops vonderwulpi*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

base, no expansion at end; genital fork tong-like, pointed at ante-lateral part and concaved at anterior margin.

Specimen examined: 1 ♀, dried, Okushiri, Hokkaido, Aug. 2, 1986, H. Sasaki.

3.3 Subfamily Tabaniinae

Genus *Atylotus* Osten-Sacken, 1876

Atylotus horvathi (**Szilady, 1926**) (Figs. 12 – 13):

Tergite 9 small triangular, and quite separated with each other, all yellowish; tergite 10 around rectangular, with some long black hair sparsely, all lightly darkened; cercus scale-like, comparatively long, lightly darkened at inner angle of base and posterior margin pointed distinctly, other part yellowish; sternite 8 star-like, with two processes darkened, anterior margin distinctly straight, and posterior margin rounded and concaved at middle, other part yellowish; spermathecae slightly expansion, fusiform and darkened; spermathecal duct long and slender, forepart lightly darkened, posterior part transparent and having mushroom-shaped expansion at end; genital fork tong-like, concaved at anterior margin, with two angles at ante-lateral and two crescent-shaped membranes at both sides.

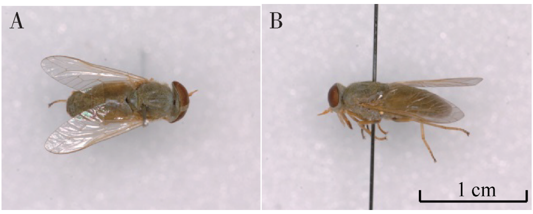

Fig. 12 Dorsal view (A) and lateral view (B) of *Atylotus horvathi*

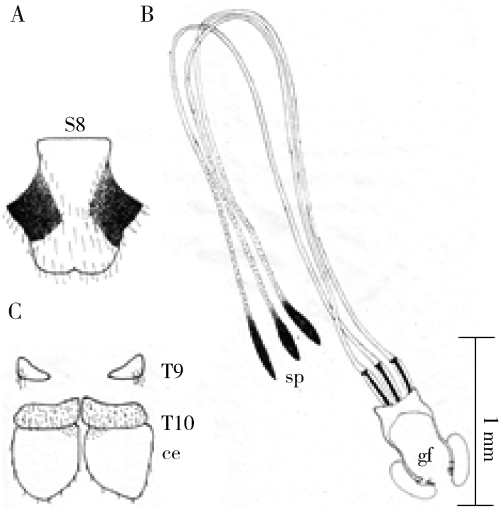

Fig. 13 Female genitalia of *Atylotus horvathi*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1 ♀, Jul. 29, 2016; 1 ♀, Aug. 15, 2016, C. Yang.

Genus *Haematopota* Meigen, 1803

***Haematopota tristis* Bigot, 1891** (Figs. 14 – 15):

Tergite 9 roughly triangle, tapering inward, slightly dark at inner angle, other part yellowish; tergite 10 yellowish, roughly oval, with distinct hairs and angles; cercus scale-like, with posterior margin processed clearly; sternite 8 processed at apical angles, yellowish except darkened laterally; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, with forepart lightly darkened, posterior part transparent, ending

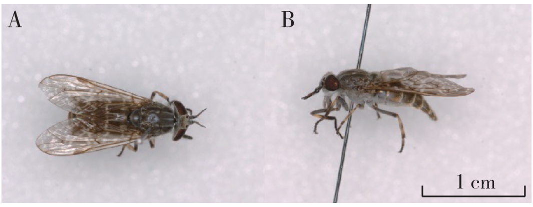

Fig. 14 Dorsal view (A) and lateral view (B) of *Haematopota tristis*

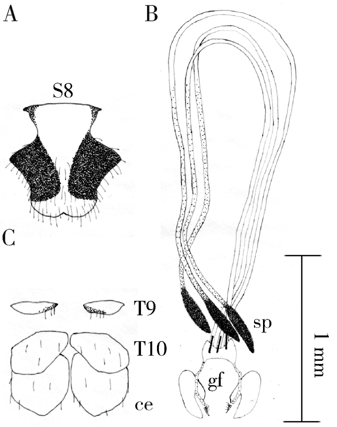

Fig. 15 Female genitalia of *Haematopota tristis*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

with mushroom-shaped expansion; genital fork elongated, anterior margin concaved, with crescent-shaped membrane at both sides.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Aug. 15, 2015; 2♀, Aug. 11, 2016, C. Yang.

***Haematopota tamerlani* Szilady, 1923** (Figs. 16 – 17):

Tergite 9 triangular, tapering inward, but comparatively slender, all lightly darkened; tergite 10 trapezoid, outer margin wider than inner margin, all lightly darkened; cercus smoothly rounded, with a light stripe at middle, and darkened at apex and base; sternite 8 star-like, comparatively short, distinctly concaved at anterior margin, lateral margin and posterior margin, around little darkened, but yellowish at middle. The spermathecae, spermathecal duct and genital fork failed to be observed.

Specimen examined: 2♀, dried, Kiyosato, Hokkaido, Jul. 19, 1989, H. Sasaki.

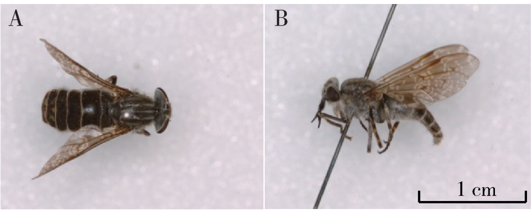

Fig. 16 Dorsal view (A) and lateral view (B) of *Haematopota tamerlani*

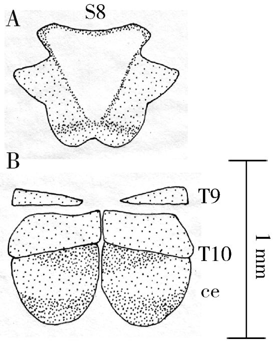

Fig. 17 Female genitalia of *Haematopota tamerlani*
A: S8: Sternite 8; B: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Genus *Hybomitra* Enderlein, 1922

Hybomitra hirticeps (Loew, 1858) (Figs. 18 – 19)

Tergite 9 triangular, tapering inward sharply, all darkened; tergite 10 roughly rectangular, all darkened; cercus wider than long, roughly rectangular, all darkened; sternite 8 star-like, anterior and lateral parts of forepart and posterior margins concaved in some extent, and darkened, other part lightly darkened, with two stripes through middle; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, having mushroom-shaped expansion at end, all lightly darkened; genital fork tong-like, with two crescent-shaped membranes, but rather slender.

Specimen examined: 1♀, stored in 70% ethyl alcohol, Tohbetsu, Hokkaido, Jun. 18, 2015, H. Sasaki.

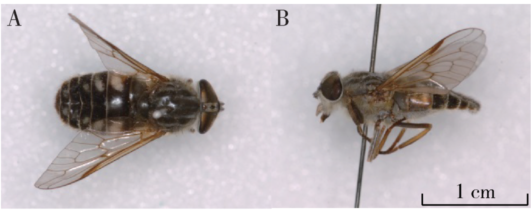

Fig. 18 Dorsal view (A) and lateral view (B) of *Hybomitra hirticeps*

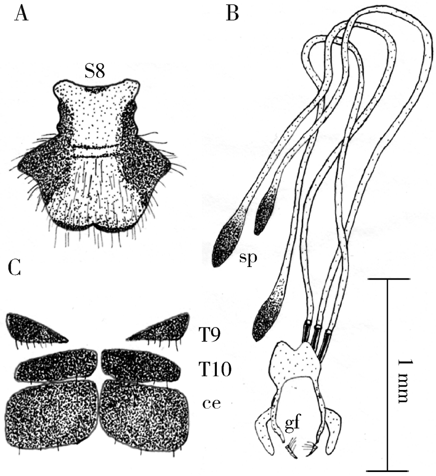

Fig. 19 Female genitalia of *Hybomitra hirticeps*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Hybomitra distinguenda (Verrall, 1909) (Figs. 20 – 21)

Tergite 9 triangular, outer margin rounded, all yellowish; tergite 10 roughly rectangular, with dull angle at apex of inner margin, all yellowish; cercus scale-like, processed at posterior margin, yellowish with some black spots at apex; sternite 8

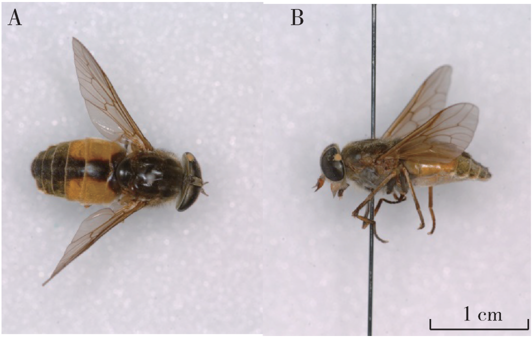

Fig. 20 Dorsal view (A) and lateral view (B) of *Hybomitra distinguenda*

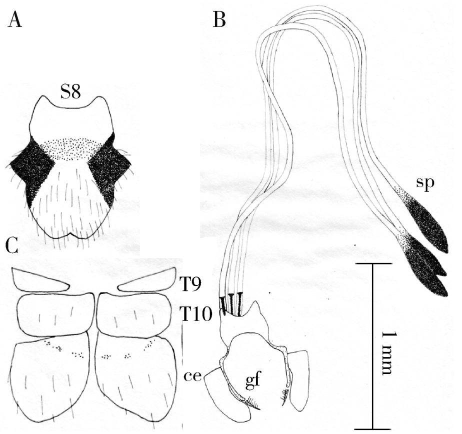

Fig. 21 Female genitalia of *Hybomitra distinguenda*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

comparatively stout, star-like, distinctly concaved at anterior margin and posterior margin, darkened at lateral parts and slightly darkened at middle; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, all transparent, having mushroom-shaped expansion at end; genital fork tong-like, with two boat-shaped membranes.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Jul. 16, 2015; 1♀, Jul. 14, 2016, C. Yang.

Hybomitra montana (**Meigen, 1920**) (Figs. 22 –23)

Tergite 9 triangular, tapering inward sharply, posterior margin smoothly rounded, all yellowish; tergite 10 roughly trapezoid, apex of outer margin concaved distinctly, all yellowish; cercus scale-like, posterior margin rounded, all yellowish; sternite 8 star-like, with two dull angles at forepart, anterior margin concaved but nearly straight, posterior margin concaved lightly, darkened at both lateral parts, the others yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, transparent, with mushroom-shaped expansions at end; genital fork tong-like, little stout, with two stout crescent-shaped membranes.

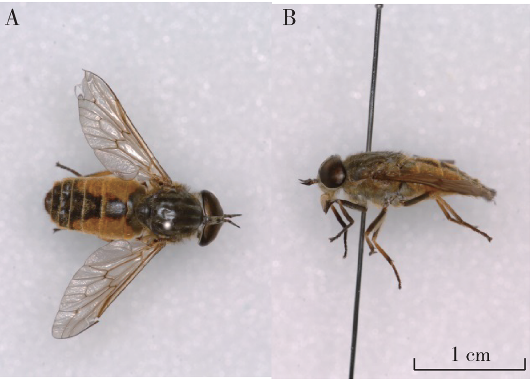

Fig. 22 Dorsal view (A) and lateral view (B) of *Hybomitra montana*

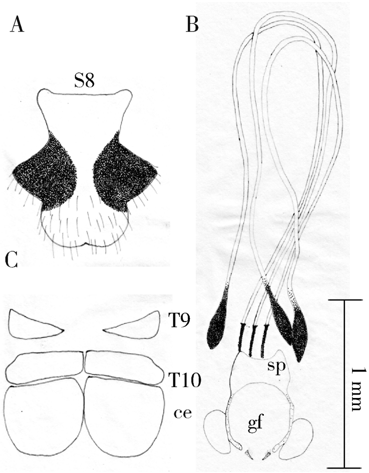

Fig. 23 Female genitalia of *Hybomitra montana*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Specimen examined: 1♀, dried, Matsuyama Moor, Bifuka, Hokkaido, Aug. 20, 2006, H. Sasaki.

Hybomitra olsoi **Takahasi, 1962** (Figs. 24 –25)

Tergite 9 triangular, comparatively small, outer margin darkened, other part lightly darkened; tergite 10 around rectangular, with apex of outer margin and inside of posterior margin concaved slightly, all darkened lightly; cercus comparatively long, scale-like, posterior part darkened extending to outside of anterior margin, other part darkened lightly; sternite 8 star-like, with anterior margin and posterior margin concaved, and darkened at lateral part, little darkened at anterior part and central part; spermathecae expanding to fusiform, darkened extending to part of spermathecal duct; spermathecal duct long and slender, transparent, with mushroom-shaped expansion at end; genital fork tong-like.

Specimen examined: 1♀, dried, Matsuyama Moor, Bifuka, Hokkaido, Aug. 20, 2006, H. Sasaki.

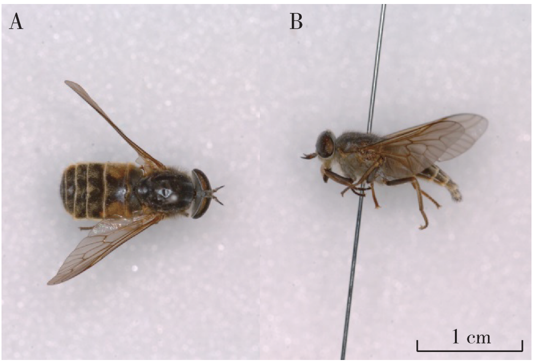

Fig. 24 Dorsal view (A) and lateral view (B) of *Hybomitra olsoi*

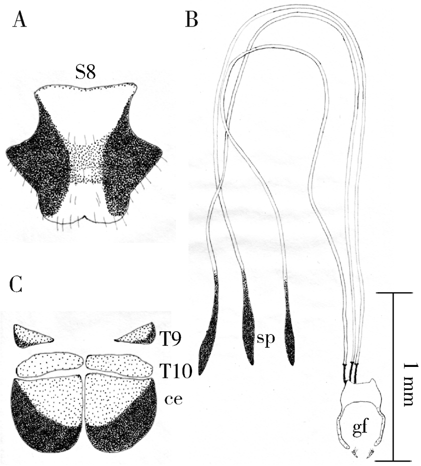

Fig. 25 Female genitalia of *Hybomitra olsoi*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Hybomitra tarandina (**Linnaeus**, **1758**) (Figs. 26 – 27)

Tergite 9 triangular, anterior margin nearly straight, with lightly darkened, posterior margin slanting inward, yellowish; tergite 10 roughly parallelogram, all darkened slightly; cercus comparatively short, rounded at posterior margin, inner angle of anterior part lightly darkened, other part yellowish; sternite 8 star-like, apical angle bluntly pointed, little darkened, anterior margin concaved and straight, lateral part darkened, having a darkened stripe at central region, posterior margin concaved distinctly, other part yellowish. The spermatheca, spermathecal duct and genital fork failed to be observed.

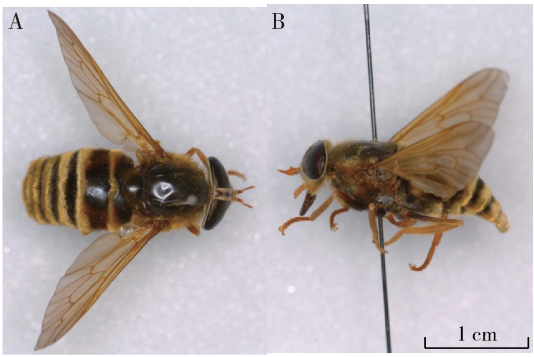

Fig. 26 Dorsal view (A) and lateral view (B) of *Hybomitra tarandina*

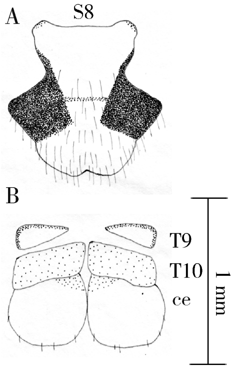

Fig. 27 Female genitalia of *Hybomitra tarandina*
A: S8: Sternite 8; B: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Specimen examined: 1 ♀, dried, Mt. Taisetsu, Hokkaido, Jul. 26, 1983, H. Sasaki.

Genus *Tabanus* Linnaeus, 1758

Tabanus chrysurus **Leow**, **1858** (Figs. 28 – 29)

Tergite 9 comparatively stout, roughly triangular, little darkened at anterior part and deeper darkened at posterior part; tergite 10 roughly triangular, tapering outward bluntly, concaved at posterior margin, all darkened slightly; cercus circular, all lightly darkened; sternite 8 star-like, with apical angle pointed sharply, anterior and posterior margin concaved, darkened at lateral part, other part lightly darkened; spermathecae expanding to fusiform, darkened; spermathecal duct long and slender, forepart darkened lightly, posterior part transparent, with mushroom-shaped expansion at

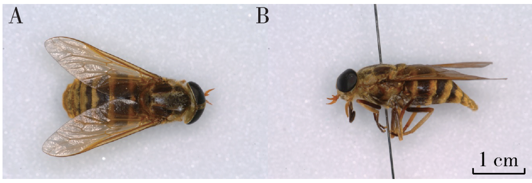

Fig. 28 Dorsal view (A) and lateral view (B) of *Tabanus chrysurus*

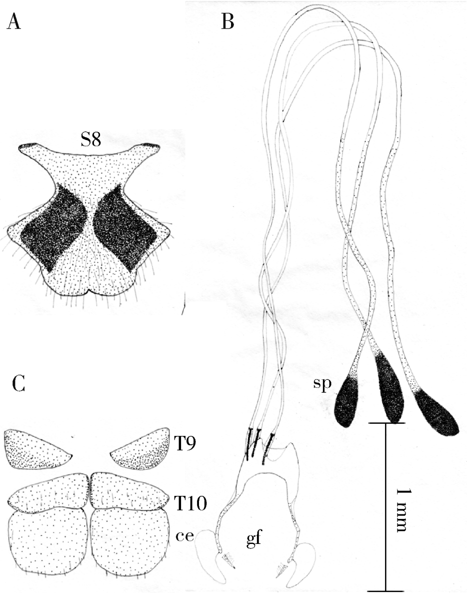

Fig. 29 Female genitalia of *Tabanus chrysurus*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

end; genital fork tong-like, with two crescent-shaped membranes.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Aug. 15, 2015; 1♀, Aug. 11, 2016, C. Yang.

***Tabanus iyoensis* Shiraki, 1919** (Figs. 30 – 31)

Tergite 9 roughly right angled triangular, all darkened lightly; tergite 10 rectangular, posterior margin concaved, all slightly darkened; cercus scale-like, posterior margin rounded, all slightly darkened; sternite 8 comparatively long, anterior margin arc-like, concaved lightly, posterior margin concaved distinctly, lateral parts darkened, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct comparatively long and slender, transparent, with mushroom-shaped expansion at end; genital fork tong-like, with two membranes.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Aug. 12, 2015; 1♀, Aug. 11, 2016, C. Yang.

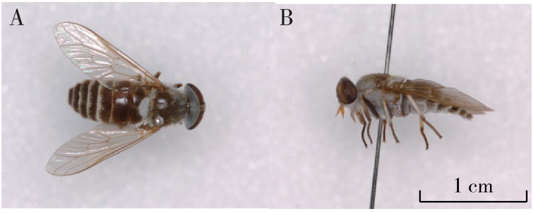

Fig. 30 Dorsal view (A) and lateral view (B) of *Tabanus iyoensis*

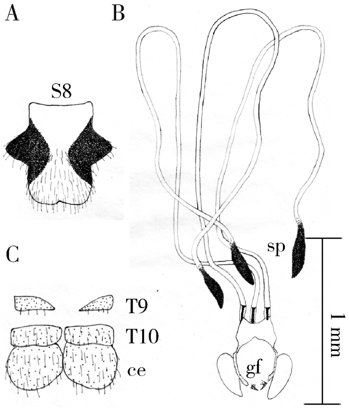

Fig. 31 Female genitalia of *Tabanus iyoensis*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

***Tabanus trigonus* Coquillett, 1898** (Figs. 32 – 33)

Tergite 9 triangular, tapering inward sharply, all lightly darkened; tergite 10 roughly trapezoid, outer margin smoothly curved downward, all darkened slightly; cercus scale-like, with posterior margin bluntly processed, all lightly darkened; sternite 8 comparatively long and slender, anterior margin and posterior margin concaved distinctly, lightly darkened at middle of anterior part, and darkened at lateral parts, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, lightly darkened at anterior part, and transparent at posterior margin, with mushroom-shaped expansion at end; genital fork tong-like.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Jul. 17, 2015; 2♀, Jul. 15, 2016, C. Yang.

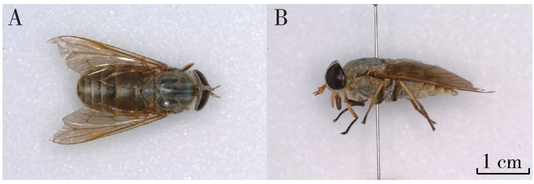

Fig. 32 Dorsal view (A) and lateral view (B) of *Tabanus trigonus*

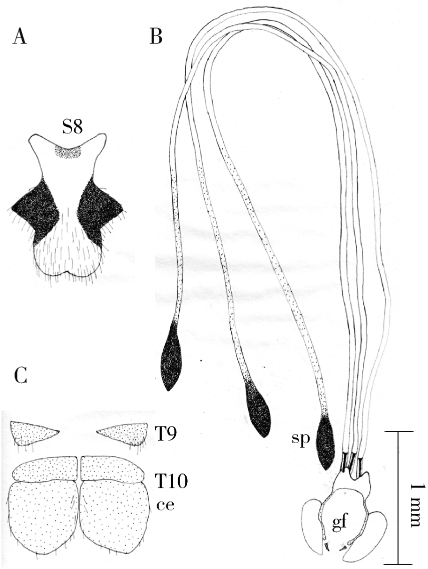

Fig. 33 Female genitalia of *Tabanus trigonus*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

***Tabanus katoi* Kono *et* Takahasi, 1940** (Figs. 34 – 35)

Tergite 9 triangular, with dull angles, all yellowish; tergite 10 trapezoid, outer margin slanting downward, little concaved at posterior margin, all yellowish; cercus roughly rounded, all yellowish; sternite 8 comparatively long and slender, anterior margin deeply concaved, posterior margin distinctly concaved, lateral parts darkened, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, transparent, with mushroom-shaped expansion at end; genital fork tong-like, membranes comparatively small.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Aug. 13, 2015; 2♀, Aug. 11, 2016, C. Yang.

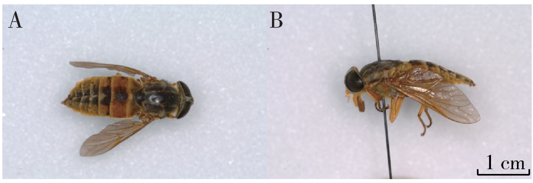

Fig. 34　Dorsal view (A) and lateral view (B) of *Tabanus katoi*

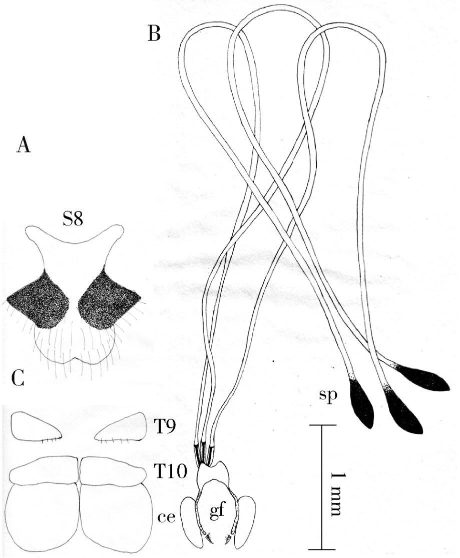

Fig. 35　Female genitalia of *Tabanus katoi*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Tabanus sapporoensis **Shiraki, 1919** (Figs. 36 – 37)

Tergite 9 triangular, tapering inward sharply, all yellowish; tergite 10 roughly trapezoid, anterior margin concaved, outer margin wider than inner margin, all yellowish; cercus scale-like, with posterior margin processed, all yellowish; sternite 8 star-like, with anterior margin straight, and two small angles at apex, posterior part bigger than anterior part, and concaved, lateral parts darkened, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, transparent, with mushroom-shaped expansion at end; genital fork tong-like.

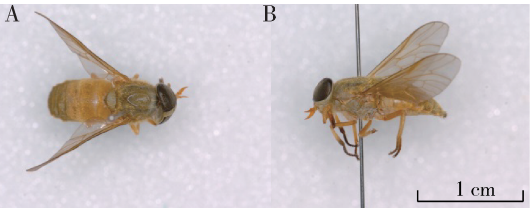

Fig. 36　Dorsal view (A) and lateral view (B) of *Tabanus sapporoensis*

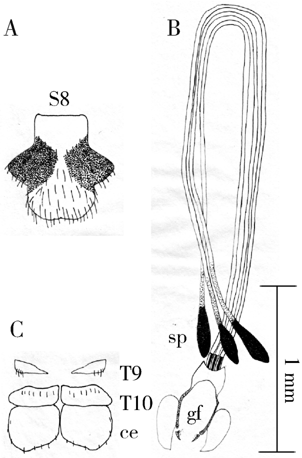

Fig. 37　Female genitalia of *Tabanus sapporoensis*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Aug. 15, 2015; 1♀, Aug. 11, 2016; 1♀, Aug. 12, 2016, C. Yang.

Tabanus fulvimediodes **Shiraki, 1919** (Figs. 38 – 39)

Tergite 9 triangular, with dull angles, posterior part lightly darkened, anterior part yellowish; tergite 10 roughly triangular, tapering inward bluntly, all slightly darkened; cercus scale-like, with posterior margin dull pointed, all yellowish; sternite 8 star-like, with anterior margin straight, posterior margin concaved deeply, lateral part darkened, with three stripes at central part, posterior part little darkened, other part yellowish; spermathecae not expanding to fusiform, belonging to a part of spermathecal duct; spermathecal duct comparatively long, slender, forepart darkened, posterior part transparent, with mushroom-shaped expansion at end; genital fork tong-like, comparatively slender, and membranes comparatively big.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Jul. 17, 2015; 1♀, Jul. 14. 2016; 1♀, Aug. 12, 2016, C. Yang.

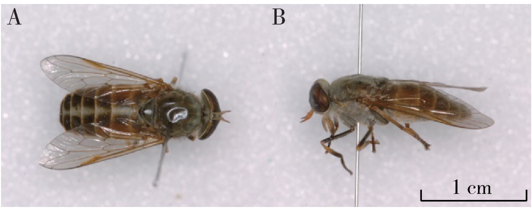

Fig. 38　Dorsal view (A) and lateral view (B) of *Tabanus fulvimediodes*

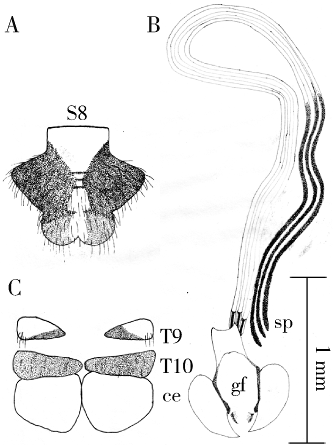

Fig. 39 Female genitalia of *Tabanus fulvimediodes*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Tabanus kinoshitai **Kono *et* Takahasi, 1939** (Figs. 40 – 41)

Tergite 9 triangular, tapering inward sharply, anterior margin little pointed at middle, all darkened lightly; tergite 10 roughly parallelogram, with apical part of outer margin little concaved, all slightly darkened; cercus scale-like, with anterior margin concaved and posterior margin processed, all lightly darkened; sternite 8 star-like, comparatively short and small, with anterior margin straight, posterior margin concaved distinctly, lateral part darkened, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct comparatively short, transparent, with mushroom-shaped expansion at end; genital fork tong-like, comparatively big, with two crescent-shaped membranes.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Jul. 3, 2015; 2♀, Jul. 1, 2016, C. Yang.

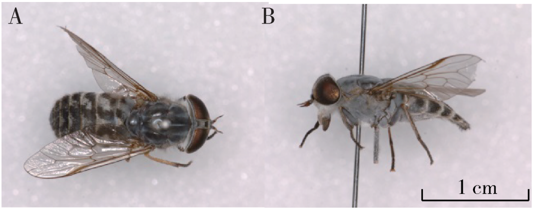

Fig. 40 Dorsal view (A) and lateral view (B) of *Tabanus kinoshitai*

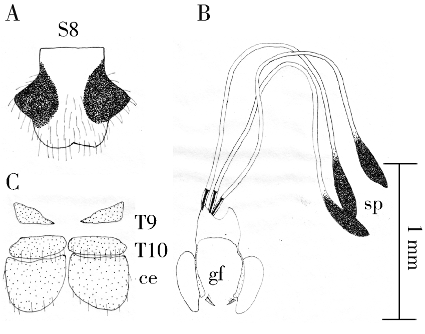

Fig. 41 Female genitalia of *Tabanus kinoshitai*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Tabanus mandarinus **Schiner, 1868** (Figs. 42 – 43)

Tergite 9 triangular, tapering inward sharply, anterior margin little darkened at middle, other part yellowish; tergite 10 roughly trapezoid, with anterior margin and posterior margin concaved, outer margin wider than inner's, all darkened slightly; cercus circular, scale-like, all darkened lightly; sternite 8 star-like, apical angles processed obviously, anterior margin and posterior margin concaved clearly, almost part darkened but forepart lightly darkened, with two stripes throughout middle part; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, with forepart lightly darkened, posterior part transparent, and with mushroom-shaped expansion at end; genital fork tong-like.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Jul. 16, 2015; 2♀, Jul. 15, 2016, C. Yang.

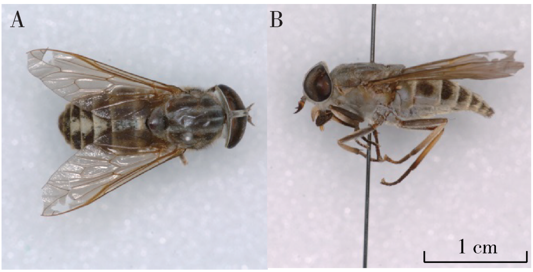

Fig. 42 Dorsal view (A) and lateral view (B) of *Tabanus mandarinus*

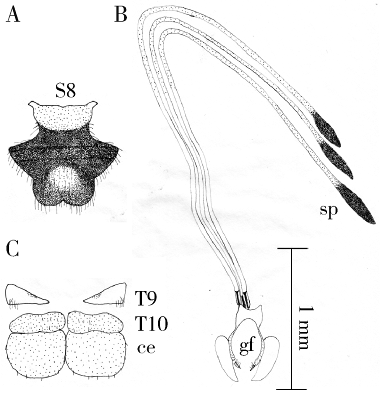

Fig. 43 Female genitalia of *Tabanus mandarinus*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Tabanus nipponicus **Murdoch** ***et*** **Takahasi, 1969** (Figs. 44 – 45)

Tergite 9 triangular, with sharp angles obviously, all yellowish; tergite 10 roughly trapezoid, outer margin wider than inner margin, with edges of anterior margin processed gently, all yellowish; cercus scale-like, posterior margin processed inward, and posterior part lightly darkened, other part yellowish; sternite 8 comparatively long and slender, anterior margin deeply concaved, and apical angles processed obviously, posterior margin also concaved, darkened at lateral part and posterior part, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, darkened at forepart, transparent at posterior part, with mushroom-shaped expansion at end; genital fork tong-like.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1 ♀, Jul. 16, 2015; 1 ♀, Jun. 30, 2016; 1 ♀, Aug. 11, 2016, C. Yang.

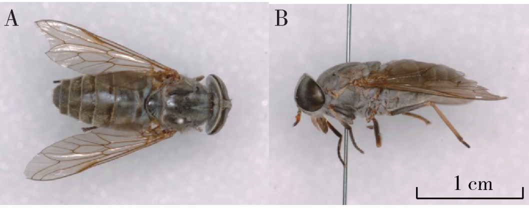

Fig. 44 Dorsal view (A) and lateral view (B) of *Tabanus nipponicus*

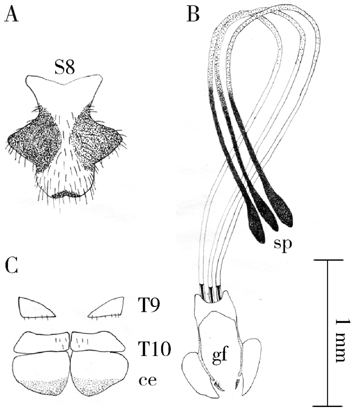

Fig. 45 Female genitalia of *Tabanus nipponicus*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Tabanus pallidiventris **Olsufjev, 1937** (Figs. 46 – 47)

Tergite 9 triangular, all yellowish; tergite 10 around trapezoid, with edges of anterior margin processed obviously, posterior margin concaved gently, outer margin wider than inner margin, all yellowish; cercus scale-like, with posterior part little darkened, other part yellowish; sternite 8 comparatively long, especially anterior part, anterior margin deeply concaved, and apical angles processed obviously, posterior margin also concaved, darkened at lateral part and posterior part, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, all transparent, with mushroom-shaped expansion at end; genital fork tong-like.

Specimen examined: 1 ♀, dried, Shizunai, Hokkaido, Jul. 28, 1990, H. Sasaki.

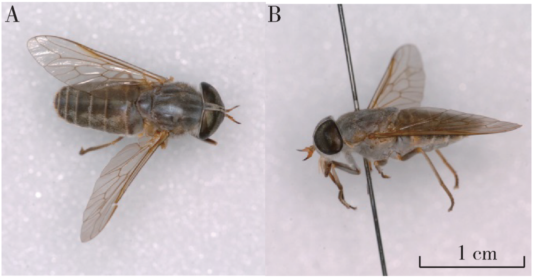

Fig. 46 Dorsal view (A) and lateral view (B) of *Tabanus pallidiventris*

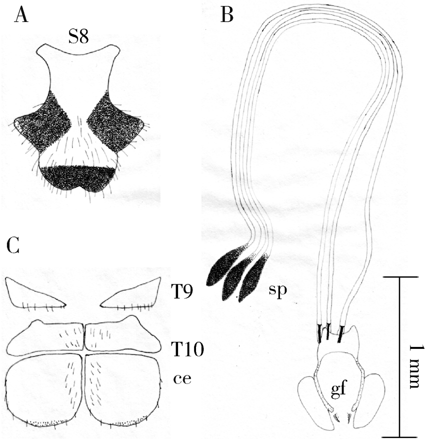

Fig. 47 Female genitalia of *Tabanus pallidiventris*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

Tabanus rufidens (**Bigot, 1887**) (Figs. 48 – 49)

Tergite 9 triangular, with outer margin darkened lightly, other part yellowish; tergite 10 roughly rectangular, with outer margin, anterior margin and posterior margin concaved distinctly, all

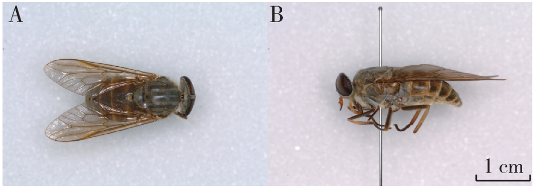

Fig. 48 Dorsal view (A) and lateral view (B) of *Tabanus rufidens*

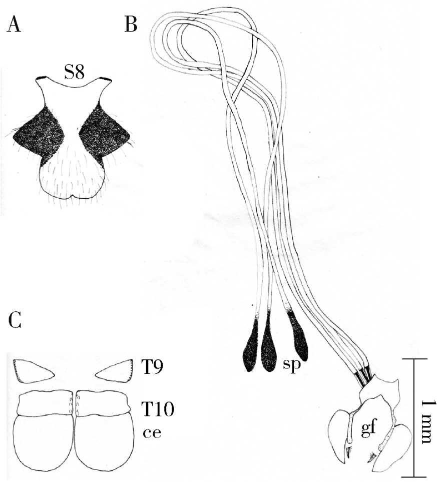

Fig. 49 Female genitalia of *Tabanus rufidens*
A: S8: Sternite 8; B: sp: Spermathecae; gf: Genital fork; C: T9: Tergite 9; T10: Tergite 10; ce: Cercus.

yellowish; cercus circular, all yellowish; sternite 8 comparatively long and stout, anterior margin deeply concaved, and apical angles processed obviously, posterior margin also concaved, darkened at lateral part and angle part, other part yellowish; spermathecae expanding to fusiform, all darkened; spermathecal duct long and slender, all transparent, with mushroom-shaped expansion at end; genital fork tong-like.

Specimen examined: Stored in 70% ethyl alcohol, Shizunai, Hokkaido: 1♀, Aug. 15, 2015; 2♀, Aug. 11, 2016, C. Yang.

3.4 Keys

Key to subfamilies and genera

1. Tergite 9 separated ······ 2
   Tergite 9 connected, sternite 8 hexagonal, spermathecae circular ······ Subfamily Pangoniiae, Genus *Stonemyia* (*S. yezoensis*)
2. Spermatecae fusiform, sternite 8 star-like, and having expansion at end of spermathecal duct ······ 3
   (Subfamily Tabaninae) Spermathecae comparatively stout, tergite 10 roughly triangular, sternite 8 water vat-like, and no expansion at end of spermathecal duct ······ Subfamily Chrysopsinae, Genus *Chrysops*
3. Anterior margin of sternite 8 concaved or flat ······ 4
   Anterior margin of sternite 8 flat and 0.5 - 0.6 mm in length, small size; tergite 9 yellowish with some long hair at outer edges of each pair; tergite 10 dark yellow and ship-shaped; cercus yellowish, only inner apex dark yellow, comparatively elongated and posterior margin pointed ······ Genus *Atylotus* (*A. horvathi*)
4. Tergite 9 roughly triangular and stout, 1/2 - 3/4 of the tergite 10 in size ······ 5
   Tergite 9 roughly triangular and comparatively slender; tergite 10 oval or trapezoid and much bigger than tergite 9 in size ······ Genus *Haematopota*
5. Tergite 9 close to tergite 10 usually; sternite 8 roughly 0.8 mm in length, moderate size ······ Genus *Hybomitra*
   Tergite 9 far away from tergite 10 usually ······ Genus *Tabanus*

Key to species in Genus *Chrysops*

1. Tergite 9 brown or dark ······ 2
   Tergite 9 yellowish or yellow ······ *C. vonderwulpi*
2. Tergite 10 brown or dark ······ 3
   Tergite 10 yellow or dark yellow ······ *C. nigripes*
3. Posterior margin of sternite 8 concaved at middle ······ *C. suavis*
   Posterior margin of sternite 8 not concaved ··· *C. japonicus*

Key to species in Genus *Haematopota*

1. Entirety slender; tergite 9 leaf-shaped; tergite 10 oval ······ *Hae. tristis*
   Entirety stout; tergite 9 wedge-shaped; tergite 10 trapezoid ······ *Hae. tamerlani*

Key to species in Genus *Hybomitra*

1. Stripes or darkened region traversing central region of sternite 8 ······ 2
   Sternite 8 yellowish excluding lateral region darkened; tergite 9 and 10, cercus also yellowish ······ *H. montana*
2. Stripes traversing central region of sternite 8 ······ 3
   Darkened region traversing central region of sternite 8 ··· 4
3. Two stripes traversing central region of sternite 8, anterior and posterior margins darkened; tergite 9 and 10, cercus also darkened ······ *H. hirticeps*
   One stripe traversing central region of sternite 8, apex darkened; anterior margin of tergite 9, tergite 10 and apical inner region of cercus dark yellow ······ *H. tarandina*
4. Posterior regions of tergite 9 and cercus darkened; the other regions and tergite 10 dark yellow ······ *H. olsoi*
   Sternite 8 doll-shaped; posterior margin of cercus pointed well, and some spots lined an arc at the anterior region ······ *H. distinguenda*

Key to species in Genus *Tabanus*

1. Sternite 8 over 1.0 mm in length, large size ······ 2
   Sternite 8 below 0.8 mm in length, moderate size and small size ······ 5
2. Tergite 9 and tergite 10, cercus all dark yellow ······ 3
   Tergite 9 and tergite 10, cercus all yellowish ······ 4
3. Sternite 8 whole dark yellow excluding darkened region of lateral part and apex; tergite 9 large and darkened at posterior region ······ *T. chrysurus*
   Sternite 8 comparatively slender, whole yellowish excluding darkened region of lateral part and dark yellow middle of anterior region; posterior margin of cercus pointed ······ *T. trigonus*
4. Apex of sternite 8 darkened; outer margin of tergite 9 darkened; long hair inserted at inner margin of tergite 10 ······ *T. rufidens*
   Sternite 8 comparatively stout, apex processed well; posterior margin of cercus pointed bluntly ······ *T. katoi*
5. Sternite 8 roughly 0.7 - 0.8 mm, moderate size ······ 6
   Sternite 8 roughly 0.5 mm, small size ······ 9
6. Stripes traversing central region of sternite 8 ······ 7
   Posterior region of sternite 8 darkened in some extent ··· 8
7. Three short stripes traversing central region of sternite 8, and anterior margin flat; spermathecae not fusiform but banding ······ *T. fulvimedioides*

Two long stripes traversing central region of sternite 8, anterior margin concaved at middle ……… *T. mandarinus*

8. Posterior region of cercus darkened lightly, posterior margin pointed sharply; entirety comparatively small …………… *T. nipponicus*

Hair inserted at inner region of cercus, posterior margin rounded; entirety comparatively large in size …………… *T. pallidiventris*

9. Tergite 9 and 10, cercus yellowish; anterior margin of tergite 10 concaved; posterior margin of cercus processed clearly …………… *T. sapporoensis*

Tergite 9 and 10, cercus all dark yellow; posterior margin of cercus rounded …………… 10

10. Spermathecal duct comparatively short, roughly 3 mm …………… *T. kinoshitai*

Spermathecal duct comparatively long, around 5 mm …………… *T. iyoensis*

4 DISCUSSION

In this article, we describe the shapes and pigmented areas of tergite 9, tergite 10, the cercus, sternite 8, the spermathecae, the spermathecal duct and the genital fork of female tabanids in Hokkaido, Japan. Based on differences in these structures, it is possible to distinguish among the subfamilies of Tabanidae.

Tergite 9 in subfamily Pangoniinae is quite different from those of subfamilies Chrysopsinae, and Tabaninae. Tergite 9 of Pangoniinae is connected, while those of the other two subfamilies are separated, being consistent with the observations reported by Mackerras (1956, 1960). Another difference is found in the shape of sternite 8, whose lateral part is large and projected, and it is not concaved at the lateral margin. The final obvious difference is the circular shape of the spermathecae (Table 1).

Table 1 Features of Pangoniinae, Chrysopinae and Tabaninae of Tabanidae

	Tergite 9	Tergite 10	Cercus	Sternite 8	Spermatheca	Spermathecal duct	Genital fork
Pangoniinae	Connected, right angled triangle, all darkened	Separated, trapezoid, all darkened	Separated, scale-like, all darkened	Anterior margin straight, posterior margin concaved, lateral part processed, hexagon	Circular, all darkened	Forepart stout, posterior part slender, no mushroom-shaped expansion at end	Tong-like, membrane peltate-like
Chrysopinae	Separated, crescent shape or triangle, all darkened or yellowish	Separated, triangle with dull outer angle, all darkened, lightly darkened, or yellowish	Separated, scale-like, all darkened, lightly darkened, or yellowish	Anterior margin processed or straight, posterior margin concaved, upper wider than lower	Stout, and long, all darkened	Forepart stout, posterior part slender, no mushroom-shaped expansion at end	Tong-like, membrane peltate-like
Tabaninae	Separated, leaves-like, or triangle	Separated, rectangle, trapezoid, and triangle	Separated, scale-like	Anterior margin concaved or straight, posterior margin concaved, lateral part pointed, and almost darkened	Almost fusiform, all darkened	Long and slender, mushroom-shaped expansion at end	Tong-like, membrane crescent-shaped

The subfamily Chrysopsinae also has several differences that can distinguish it from the other two subfamilies. First, the shape of tergite 10 is roughly triangular with a dull outer angle. Second, the shape of sternite 8 looks like a water vat: its anterior margin is the widest, and there is no visible process at the lateral margin. Next, the spermathecae are comparatively big, and connect smoothly with the spermathecal duct. And finally, the shape of the genital fork membrane is peltate. These results are consistent with those of Iwata and Nagatomi (1976) (Table 1).

Distinguishing differences of the subfamily Tabaninae are seen in the shape of the lateral part of sternite 8, the shape of the spermatheca, the shape of the end of the spermathecal duct, and the shape of the genital fork membrane. The lateral part of sternite 8 is always pointed, and the spermathecae expand fusiformly, except in *T. fulvimedioides*. The end of the spermathecal duct has a mushroom-shaped expansion; and genital fork membrane is roughly crescent-shaped. We did not find great variability of the cercus and the genital fork as found by Murdoch and Takahasi (1959). Instead, tergite 10, the spermathecae, and the mushroom-shaped ends of the spermathecal ducts show more variation in taxonomic value (Table 1).

Among genera, it is difficult to establish a way to determine the common points. Among species, similarities are seen only within the genus *Chrysops*. In other genera, the species are diversified. The same conclusion was reached by Mackerras (1956).

Therefore, for genus- and species-level classification, it is necessary to examine the combined characteristics of tergite 9, tergite 10, the cercus, sternite 8, the spermathecae, the spermathecal duct and the genital fork.

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日本北海道虻类雌性外生殖器形态(双翅目:虻科)

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摘要:【目的】利用日本北海道虻类评估和验证外生殖器在分类学上的意义。【方法】将虻类成虫标本浸渍在生理盐水中并置于双目显微镜下通过针和镊子在培养皿中进行解剖并绘图,观察第9背板、第10背板、尾叶、第8腹板、受精囊、受精囊管及生殖叉器的形态特征。【结果】在日本北海道共记录了虻科(Tabanidae) 3亚科7属38种。我们观察并描述了3亚科其中的6属24种的雌性外生殖器的主要特征。亚科之间存在明显差异;然而在一般情况下属之间很难建立一种方法来确定共同点;种之间只有在斑虻属 *Chrysops* 中有相似之处,其他属中则比较多样化。因此,亚科鉴定根据第9背板、第8腹板及受精囊足以进行区分,属及种鉴定需要结合第9背板、第10背板、尾叶、第8腹板、受精囊、受精囊管及生殖叉器各自的特征组合在一起才能区分开来。我们也制作了虻类外生殖器的检索表。【结论】和许多其他昆虫一样,外生殖器是虻科的重要分类特征,对于促进分类学和系统学的发展具有重要意义。本研究首次对分布在日本北海道的虻科雌性外生殖器进行了系统研究。

关键词: 双翅目; 虻科; 分类; 雌性生殖器; 形态; 北海道; 日本

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